reduced hemoglobin, forming nitrosyl-hemoglobin, which is then oxidized to methemoglobin with the production of nitrites and nitrates. Provided methemoglobin levels in the blood remain below 5%, this leads to no clinically important problems. Inhaled nitric oxide does get into platelets and prolongs bleeding time, which has raised the concern that this might lead to an increased risk for neonatal intracranial bleeding. Nitric oxide and its oxidation products (NO_2, NO_x) may also cause direct pulmonary toxicity, particularly to immature lungs. Current occupational safety and health standards consider exposure to 25 ppm for an 8-hour time-weighted average safe. Pulmonary vasodilator concentrations of nitric oxide currently used are in this range, but therapy with nitric oxide will usually involve a 24-hour exposure rather than 8 hours.

Most investigators feel that inhaled nitric oxide is still an experimental therapy, but some centers are currently using inhaled nitric oxide for clinical indications, outside of experimental protocols. Theoretically, any center, large or small, could avail itself of the equipment and know-how to administer inhaled nitric oxide at this stage. Undesirable effects of this might include delayed referral of patients needing level III care and exposure of patients to a possibly toxic gas before its indications, contraindications, and side effects have been fully elucidated by randomized controlled trials in progress.

ALFONSO SOLIMANO, MD
Vancouver, British Columbia

REFERENCES

Abman SH: Pathogenesis and treatment of neonatal and postnatal pulmonary hypertension. Curr Opin Pediatr 1994; 6:239-247

Frostell C: Nitric oxide inhalation—Future drug or an invitation to disaster? Paediatr Anaesth 1994; 4:147-150

Moncada S, Higgs A: The L-arginine-nitric oxide pathway. N Engl J Med 1993; 329:2002-2012

Dialysis and Renal Transplantation of Infants

OBSTRUCTIVE UROPATHY, renal dysplasia, and renal cortical necrosis are the most common causes of end-stage renal disease in infants. An interesting occurrence is that asphyxia in the newborn period can damage kidneys out of proportion to brain, leaving an infant with renal cortical necrosis but good potential for intellectual development. Oxalosis and severe congenital nephrotic syndrome are infrequent causes of renal failure.

When infants with severe renal disease fail to grow with conservative management, dialysis may be needed to help an infant grow to a size suitable for transplantation. Dialysis is usually prescribed as a vigorous peritoneal dialysis program, with the infant receiving 12 or more exchanges a day. Besides this dialysis prescription, adequate nutrition must be provided. Infants with renal failure generally have poor appetites, and 90% of them need nasogastric tube feeding or gastrostomy feeding. Daily energy intakes of as much as 140 kcal per kg of body weight may be needed. With such a dialysis and nutrition program, however, growth and development can be well supported and transplantation undertaken if the renal disease does not resolve.

Kidney transplantation is the therapy of choice for infants and children with end-stage renal disease. Transplantation has been accomplished in infants as small as 4.5 kg (10 lb), but is more easily done, with less risk, once the infant has reached 8 to 10 kg (18 to 22 lb). At this size, when the transplantation is done at a center with both a surgeon and nephrologist experienced in caring for infants, the results approach those attained in larger children. Patient survival rates are above 95% at one year and graft survival above 90%. Most donors (70%) used for infants and small children are living-related, usually a parent. Best results are obtained with the use of living donors. Cadaver donors younger than 6 years are not suitable because of rates of graft thrombosis and technical complications.

The kidney is placed in the peritoneal cavity, with anastomoses of the renal artery and vein end-to-side to the aorta and inferior vena cava. The kidney most often lies on the right side, and the right native kidney may be removed to make room. Both native kidneys are removed only if they are thought to be a risk for infection or the cause of severe hypertension. In the immediate postoperative period, urine output is high, but the adult kidney accommodates to the infant's physiology within days.

Infants and small children usually grow and develop well after transplantation. Most are maintained on triple immunosuppressive therapy consisting of azathioprine, cyclosporine, and low-dose prednisone. Tacrolimus (Prograf, called FK 506 during clinical trials before US Food and Drug Administration [FDA] approval) is similar to cyclosporine in action and has recently been approved by the FDA for use in patients with liver transplants. It may also have a role in kidney transplantation, particularly in patients who do not tolerate cyclosporine or who absorb it erratically. Tacrolimus is absorbed rapidly from an empty stomach. New and better immunosuppressive regimens, with better efficacy and fewer side effects than this triple therapy, are on the horizon. If a transplanted kidney does fail, retransplantation is possible.

SUSAN B. CONLEY, MD
Stanford, California

REFERENCES

Conley SB, Al-Utri A, So S, Salvatierra O: Prevention of rejection and graft loss with an aggressive quadruple immunosuppressive therapy regimen in children and adolescents. Transplantation 1994; 57:S40-S44

Stablein DM, Tejani A: Five-year patient and graft survival in North American children: A report of the North American Pediatric Renal Transplant Cooperative Study. Kidney Int 1993; 43:516-521

Sedation for Pediatric Procedures

THE INCREASE IN the number of diagnostic and therapeutic procedures done on infants and children over the past decade has led to an increased use of sedation for these patients. Imaging studies, bone marrow aspirations, lumbar punctures, dental procedures, cardiac catheterizations, and endoscopies are commonly done with sedation in hospitals and ambulatory clinics. The American Academy of

Pediatrics Committee on Drugs and the Joint Commission on Accreditation of Healthcare Organizations have focused attention on the care and comfort of infants and children during these procedures. The promotion of practice guidelines by these organizations is aimed at reducing risk and ensuring quality by reducing variations in practice.

The decisions to perform a procedure and to sedate a patient are independent of one another. Too often physicians ignore nonpharmacologic methods, such as sleep deprivation and natural sleep, cuddling, and distraction, that can be successful and eliminate or reduce the need for sedating drugs. A rational approach requires the answers to a series of questions about the procedure: Is it painful? How long must the patient be sedated? Is immobility necessary? Is this procedure an emergency? The answers, combined with a careful assessment of the patient, allow individual decisions to be made. The assessment includes a medical history and physical examination, looking for a history of apnea, seizures, previous sedations, cardiopulmonary problems, current medication use, or recent illness. The examination may reveal a possible airway problem. There is no doubt that the time and effort involved in this aspect of the sedation process will yield a great return in terms of patient safety and success of the procedure. Thoughtful physicians will then be in a position to assign the level of risk, to choose the appropriate drug, and to ensure patient safety with the most appropriate monitoring and personnel.

The level of sedation achieved when administering sedative drugs ranges from conscious sedation to a level near that of general anesthesia. Recognizing this continuum of sedation and individual patient variability in response to sedating drugs, it is mandatory that patients be monitored and assessed throughout the procedure and recovery. The safety net includes the regular assessment of physiologic variables by personnel trained in basic life support and immediately available emergency equipment and a responsible physician. Protocols are necessary to ensure consistency, but in any situation, vigilant attention to the patient is key.

A recent survey of current practice in which the first three choices for sedation were chloral hydrate, DPT (meperidine hydrochloride [Demerol], promethazine hydrochloride [Phenergan], and chlorpromazine hydrochloride [Thorazine]), and pentobarbital indicates that clinicians use drugs that are familiar to them. Many alternative pharmacologic agents are available that have more desirable properties and fewer side effects than these agents.

Medications available to clinicians fall into several categories. Sedative-hypnotic drugs include barbiturates, benzodiazepines, and major tranquilizers (butyrophenones). Characteristics such as rapidity of onset, duration of effect, and side effects vary widely. For example, barbiturates enhance the perception of pain despite their sedative properties, whereas butyrophenones enhance the effects of analgesics. The choice between these two classes of drugs, therefore, should be influenced by whether or not the procedure planned will be painful to the child.

Opiates—often referred to as narcotics—are primary analgesics with sedative side effects, and all are potent respiratory depressants. Several new synthetic opiates are short-acting and are ideal for brief painful procedures because they do not leave the child depressed for a lengthy period. Local anesthetics are important to use in every case in which the medical procedure involves any degree of pain because the local anesthetic will reduce the required dose of opiates or sedatives, thus increasing the safety to the patient.

Adjuvant medications such as the nonsteroidal antiinflammatory drugs, particularly the newer parenteral drug ketorolac tromethamine (which is not yet approved for pediatric use), have analgesic effects nearly equal to those of the opiates and are devoid of respiratory depression, thereby reducing the opiate requirement and enhancing safety. General anesthetics, such as nitrous oxide, ketamine hydrochloride, and propofol in subanesthetic doses, can occasionally be used by nonanesthesiologists. We recommend training and experience as a prerequisite to the use of such drugs and adherence to strict protocols to prevent trespass into the realm of general anesthesia by nonanesthesiologists. Each drug, furthermore, has important dose limitations, side effects, and possible complications of which physicians must be aware.

Each institution must develop therapeutic guidelines based on local practice and institutional experience. Departments of anesthesia are increasingly being consulted in the development of protocols and guidelines. This trend is entirely appropriate because new pharmacologic agents are often introduced as anesthetic agents. The administration of sedation will remain most often in the practice of nonanesthesiologists, however. Each practitioner must define the scope of practice based on personal knowledge and skills and seek appropriate consultation for those patients who are beyond that scope.

THEODORE C. SECTISH, MD
ELLIOT J. KRANE, MD
Palo Alto, California

REFERENCES

Cook BA, Bass JW, Nomizu S, Alexander ME: Sedation of children for technical procedures: Current standard of practice. Clin Pediatr 1992; 31:137-142

Cote CJ: Sedation for the pediatric patient: A review. Pediatr Clin North Am 1994; 41:31-58

Kaufmann RE, Banner W, Berlein CM, et al: Guidelines for monitoring and management of pediatric patients during and after sedation for diagnostic and therapeutic procedures. Pediatrics 1992; 89:1110-1115

ADVISORY PANEL TO THE SECTION ON PEDIATRICS